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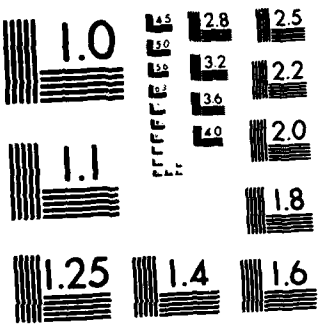

Fraunhofer-Institut für Kurzzeitdynamik
Ernst-Mach-Institut
Abteilung für Ballistik

ELECTRICAL IGNITION OF HAN-BASED LIQUID PROPELLANTS

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(Principal Investigator)

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Contract No. DAJA 45-86-C-0029

Fourth Interim Report

October 1987 - March 1988

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A. Objectives

The present Fourth Interim Report informs on the current status of the Contract No. DAJA 45-86-C-0029, entitled: "Electrical Ignition of HAN-Based Liquid Propellants". This contract is supported and sponsored by the U. S. Government through its U. S. Army Research, Development and Standardization Group in the United Kingdom (U.S.A.R.D.S.G. - UK).

The scope of this study is to investigate and optimize the electrical ignition of hydroxylammonium nitrate (HAN)-based liquid monopropellants (LP) in conjunction with its use as a propellant charge in the regenerative liquid propellant gun (RLPG). In this research, the fundamentals of LP ignition will be investigated which will contribute to the design of electrical igniter devices suitable for large caliber RLPG systems. Specific goals are:

- to investigate various means of electrical ignition of LP;
- to develop quantitative ignition criteria;
- to achieve reproducible igniter output energies;
- to obtain igniter energy effluxes that are capable of starting the regenerative process and producing sustained ignition in the gun chamber;
- to scale the ignition requirements to large volumes.

B. Research Efforts Proposed for the Research Period October 1987 to March 1988

In the Fourth Interim Research Program, i.e., during the period October 1, 1987 to April 1, 1988 it was proposed to

- alter the confinement,
- build advanced test fixtures, and to
- measure ignition parameters for various test conditions.

C. Work Done During the Reporting Period

As our experience with the experimental apparatus increased, we realized that its mechanical and electrical stability was still inadequate. In the test fixture's initial design (Figure 1) the cathode was deformed, due to the rapid combustion during the ignition. Furthermore, the base insulator which forms the lower half of the ignition chamber was invariably destroyed in each firing. The resulting contact between the electrodes gave rise to steep current pulses thereby destroying vital components of the circuitry. Figure 2 shows the time evolution of the current in such an experiment.

We decided to redesign the electrode support coverting it to a multi-piece concept (Figure 3). The main structural features ensuring the assembly's shock absorbing capacity are the enlarged cylindrical steel collar at the electrode base and the teflon and especially the nylon ring used in the base insulation piece.

For simplicity's sake only, one of the BRL type igniters (Figure 4a) was used during the redesign phase and the reproducibility tests. This phase of the project, now completed, lasted through the month of March. Table 1 shows data from this test series (Exp. Nos. 25 to 34). The excellent reproducibility is visualized by the p(t) curves shown in Figure 6. The variability in the rise times is caused mainly by slight differences in the actual vent diameters, each firing resulting in a minor widening of the orifice. With the original diameter of 2 mm (Figure 4a) the ignition was poor, sometimes not occurring at all.

In addition to the aforementioned activities we started a series of ignition experiments with an igniter of our own design (Figure 4b). The preliminary results are quite encouraging as shown by the data in Table 1. The energy required for ignition is significantly lower (see Exp. Nos. 35 and 36 in Table 1) than for the firings in which the modified BRL type cavity design was deployed (Exp. Nos. 25 to 34 in Table 1). Furthermore, we found that a vent diameter of 2 mm is too large for successful ignition.

In this case, the liquid propellant is merely ejected from the cavity because of the poor confinement. This result is in agreement with analogous observations obtained in tests with the BRL type configuration.

In accordance with the research proposal two new test fixtures were designed and built at EMI-AFB. The first version corresponds to a slightly modified BRL type fixture (not shown). The more sophisticated second version (Figure 5) retains the overall dimensions of the first but differs considerably in a variety of features. Most conspicuous are the sapphire window ports included for observations by photographic techniques and for laser monitoring of the ignition chamber. The new fixtures differ mainly in electrode design. The windowless version is suited for further testing of the ignition chamber types used to date (see above). On the other hand, the design shown in Figure 5 will be developed for the study of new electrode geometries. These new electrode geometries include the fundamental configurations (a) needle/plate, (b) plate/plate, and (c) sphere/plate electrodes. Both chambers enable the simultaneous monitoring of the ignition and combustion chamber pressures. Preliminary tests with these two chambers are under way.

D. Brief Statement of Research Plans 1988

Research plans for the next six months are to

(1) measure ignition parameters in the newly designed chambers using the various electrode configurations,

(2) scale the ignition requirements to larger volumes.

E./F. Visits, List of Papers, etc.

The principal investigator attended the Tenth International Symposium on Ballistics, San Diego, CA, 25 to 29 October 1987 to present a paper on liquid propellant studies and the DEA-G-1060 Meeting held subsequently during the week 1 to 7 November 1987 at the BRL, APG, MD.

G. Significant Administrative Actions

A full-time technician has been employed by the Fraunhofer Society supported by this contract.

H. Amounts of Funds and Property Acquired

No ununsed funds remain on the contract, since we are awaiting the fourth partial payment. Also, no property was acquired with contract funds during the reporting period.

Weil am Rhein, April 1, 1988

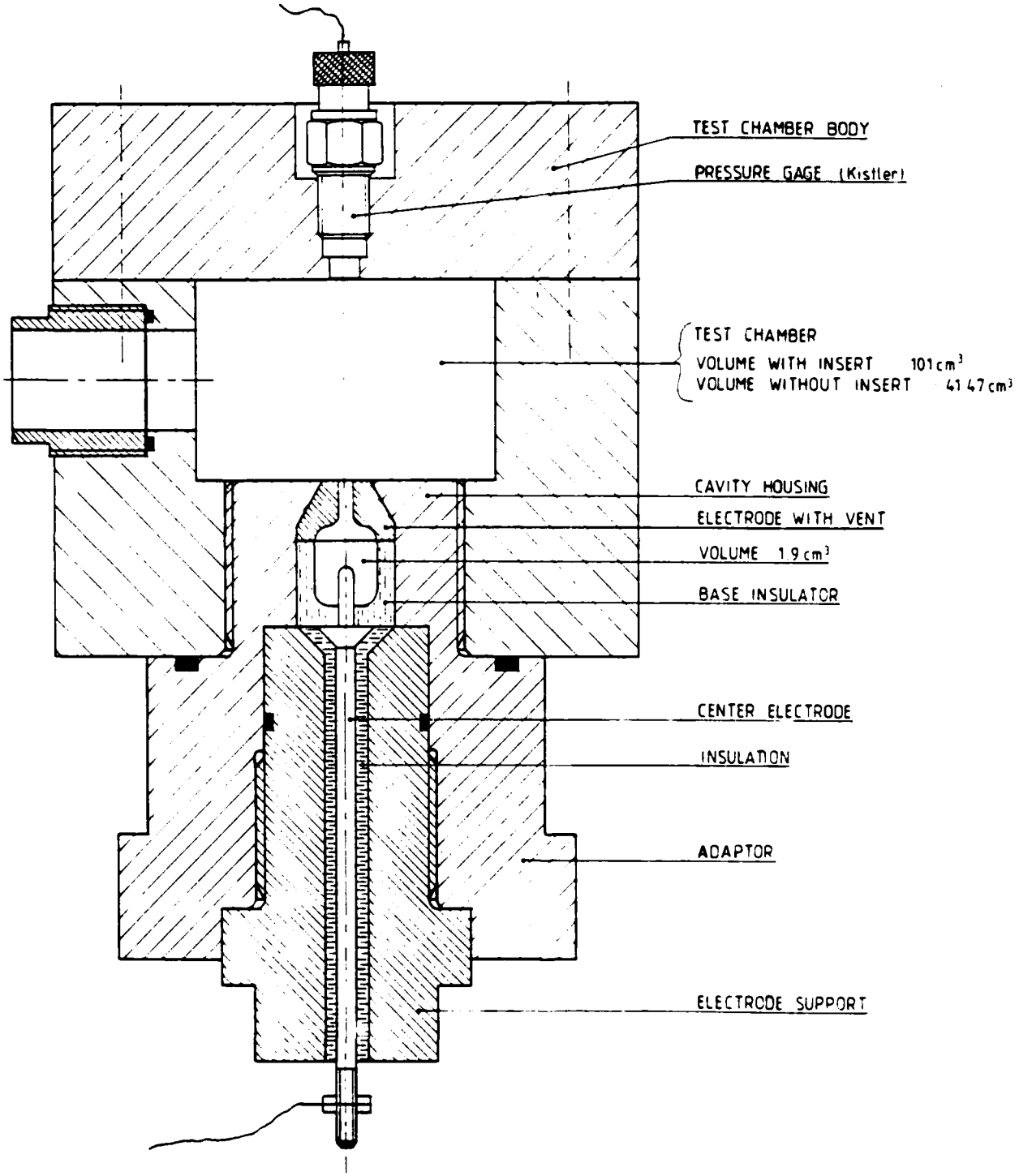
Guenter Klingenberg
(Principal Investigator)

Table 1: Tests done during March 1988

Cavity: Test Nos. 25 to 34 BRI type (Fig. 4a); Test Nos. 35 and 36 EMI-AFB design (Fig. 4b)

Test No.	Orifice Diam. [mm]	Volume of LP [ml]	Current I [A]	Voltage U [V]	Power P [kW]	Energy E [J]	Pressure p_{max} [MPa]	Rise time Δt [ms]
25	1.8	1.9	121	1610	-	-	> 16	4.9
26	1.8	1.9	128	1625	-	-	> 15.7	5.2
27	1.8	1.9	129	1600	184	101	> 16.7	3.9
28	1.8	1.9	128	1600	184	101	> 16.5	3.9
29	1.8	1.9	127	1620	184	94	> 16.0	4.0
30	1.8	1.9	130	1660	193	91	> 15.9	4.0
31	1.6	1.9	132	1700	192	79	> 16.4	2.4
32	1.6	1.9	147	1660	225	88	> 15.1	2.9
33	1.8	1.9	144	1620	220	96	> 13.6	3.0
34	1.8	1.9	127	1620	200	92	> 15.0	3.6
35	2.0	1.9	185	1500	230	65	-	no ignition
36	1.6	1.9	185	1540	230	65	> 14.0	2.0

Figure 1: TEST FIXTURE
ELECTRICAL IGNITION OF HAN-BASED LP



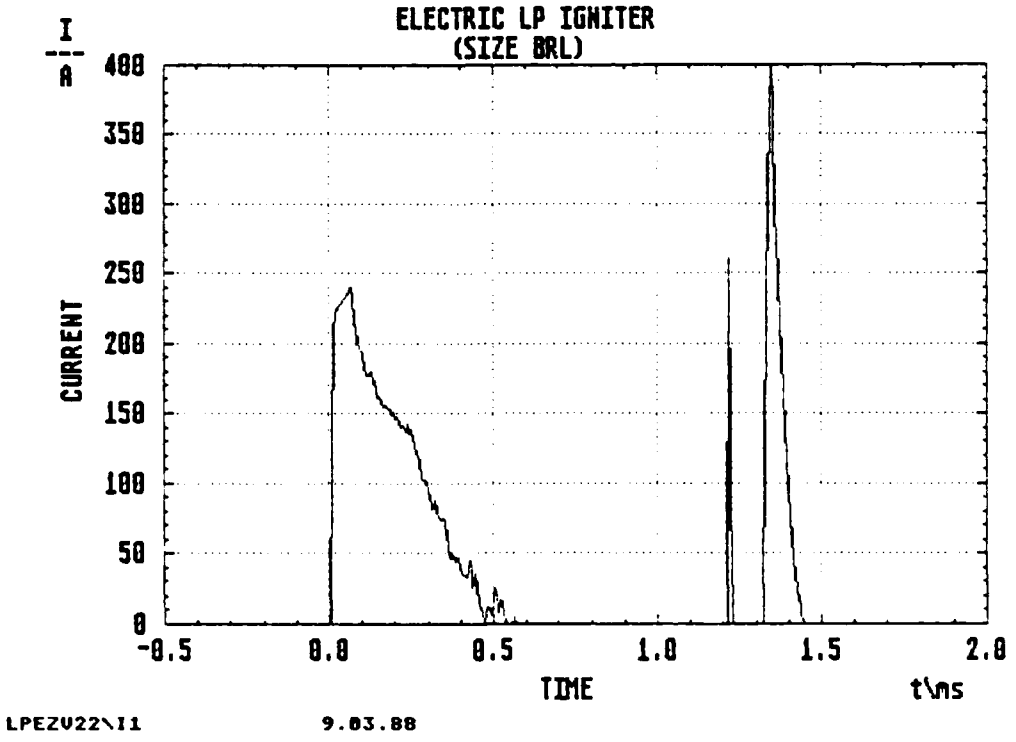
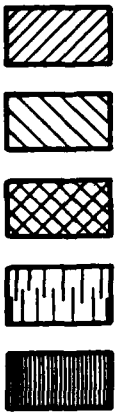


Figure 2: Current versus time diagram. The pulse at 1.2 ms is generated by a short circuit. The signal at 1.4 ms is caused by induction effects.



Steel

Nylon

Glass ceramics

Teflon

Plastic

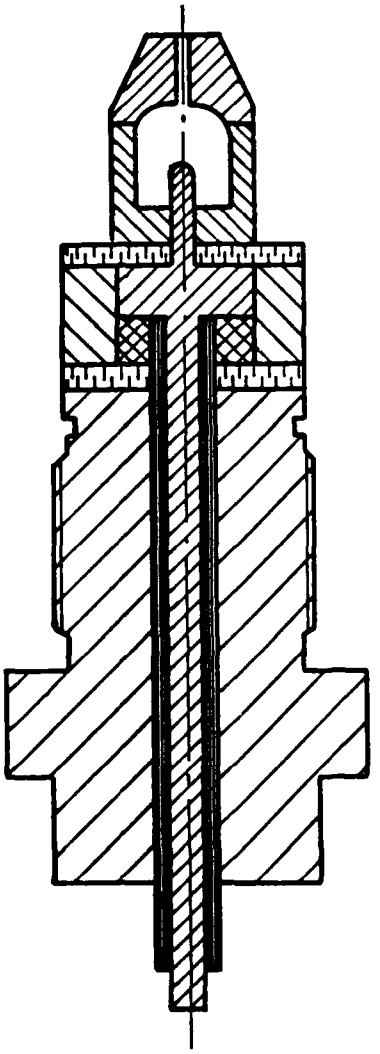
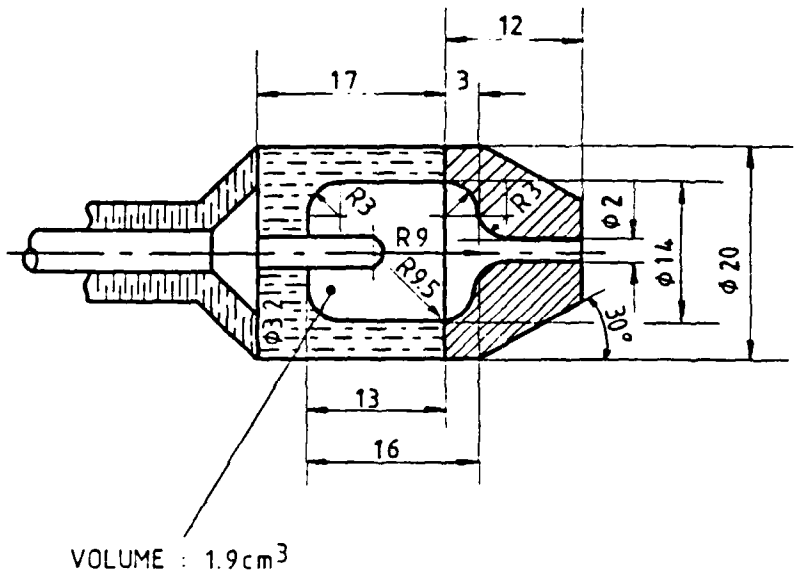


Figure 3: Electrode support

IGNITER CAVITY CONFIGURATION

a)



b)

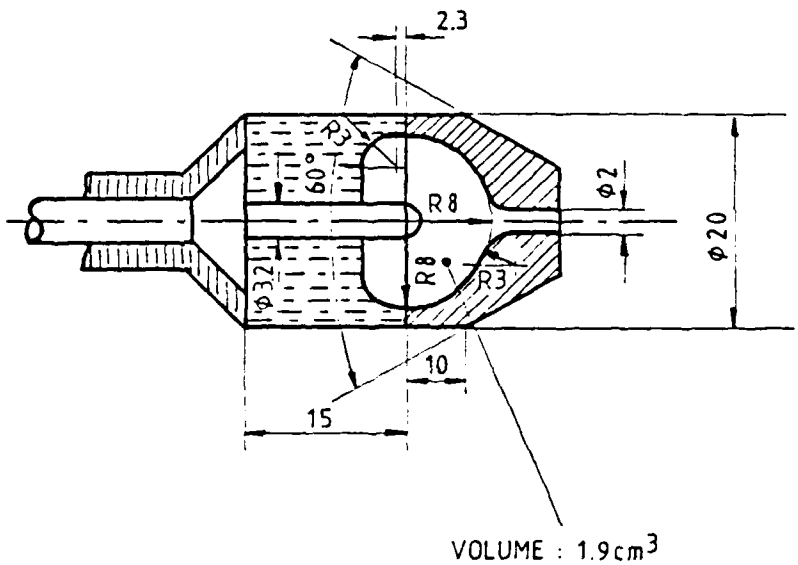


Figure 4: Igniter cavity configuration

a) Type: BRL

b) Type: EMI-AFB

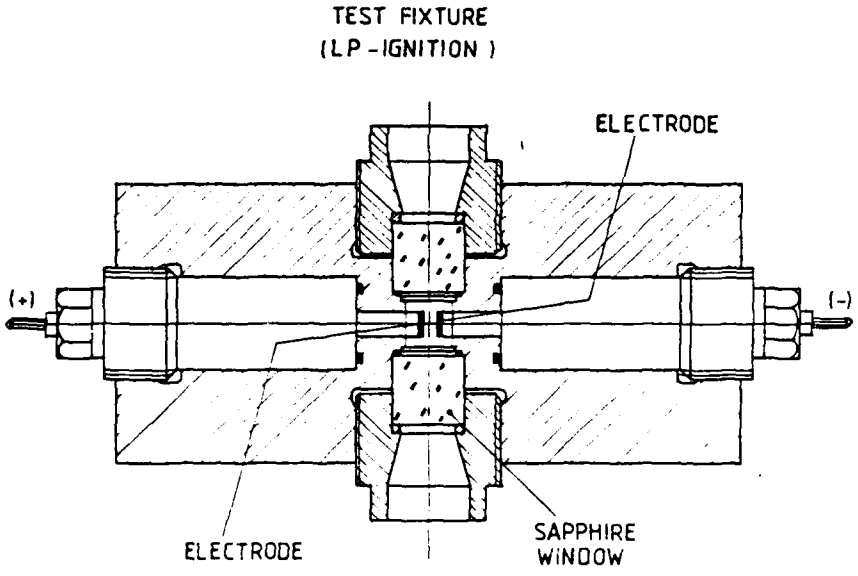


Figure 5: Test fixture with sapphire windows as designed by EMI-AFB.
Ports for the pressure gauge and the rupture disk are placed on the axis running through the center of the apparatus perpendicular to the plane of the paper.

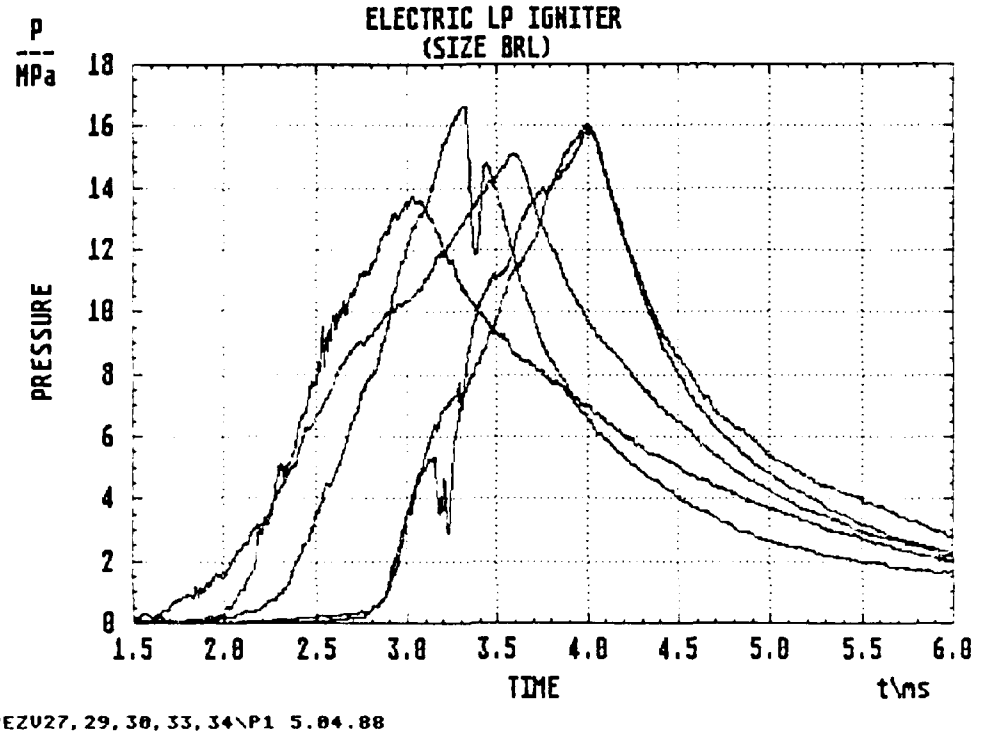
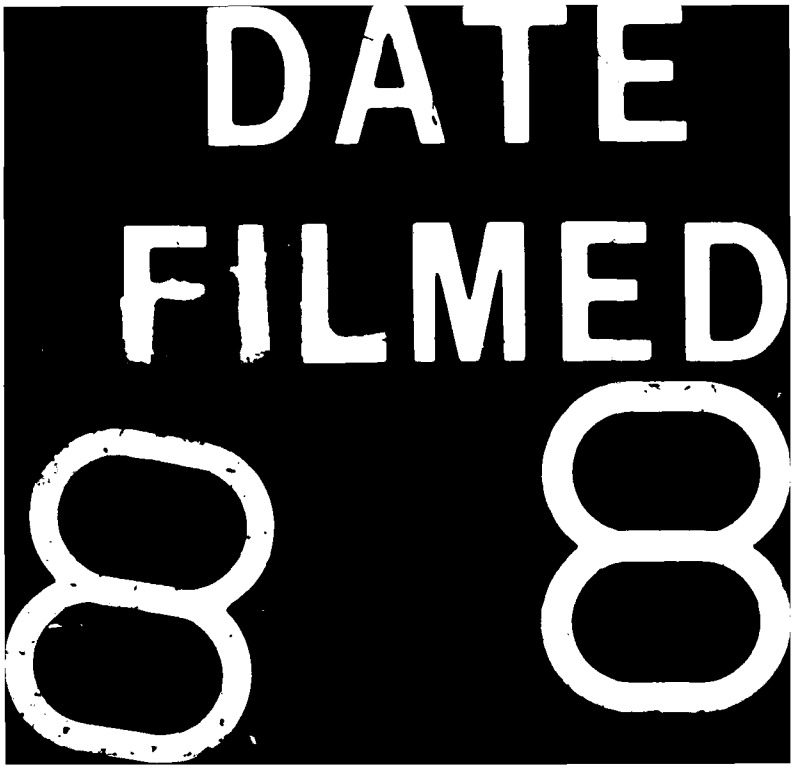


Figure 6: Comparison of pressure versus time curves for Test Nos. 27 and 29 to 34. Maximum pressure limited by rupture of blow-out disk. Time delay (ignition delay) determined by vent diameter.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